CLAIMS

[0051] What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A method for conducting atomic layer deposition of rhodium on a substrate comprising the steps of:

positioning said substrate in a deposition region of a reactor chamber;

introducing a rhodium group metal precursor into said reactor chamber to deposit a rhodium monolayer on said substrate; and

introducing oxygen into said deposition region to remove carbon from said rhodium monolayer.

2. The method of claim 1, wherein said rhodium group metal precursor comprises an organic rhodium group metal precursor having the formula Ly[Rh]Yz, wherein L is independently selected from the group consisting of neutral and anionic ligands; y is one of {1, 2, 3, 4}; Y is independently a pi-orbital bonding ligand selected from the group consisting of CO, NO, CN, CS, N_2, PX_3, PR_3, $P(OR)_3$, AsX_3, AsR_3, $As(OR)_3$, SbX_3, SbR_3, $Sb(OR)_3$, NH_xR_{3-x}, CNR, and RCN, wherein R is an organic group, X is a halide and x is one of {0, 1, 2, 3}; and z is one of {0, 1, 2, 3, 4}.

3. The method of claim 2, wherein said rhodium group metal precursor is dicarbonyl cyclopentadienyl rhodium.

4. The method of claim 1, wherein said atomic layer deposition is performed at a temperature of about 100°C to about 200°C.

5. The method of claim 4, wherein said atomic layer deposition is performed at a temperature of about 100°C to about 150°C.

6. The method of claim 1, wherein said rhodium group metal precursor is introduced into said reactor chamber at a rate of about 0.1 to about 500 sccm.

7. The method of claim 1, wherein said rhodium group metal precursor is introduced into said reactor chamber at a rate of about 0.1 to about 5 sccm.

8. The method of claim 1, wherein said oxygen is introduced into said reactor chamber at a rate of about 1 to about 500 sccm.

9. The method of claim 8, wherein said oxygen is introduced into said reactor chamber at a rate of about 10 to about 200 sccm.

10. The method of claim 1 further comprising introducing a first gas into said reactor chamber after said step of introducing said rhodium group metal precursor and before said step of introducing oxygen.

11. The method of claim 10, wherein said first gas is selected from the group consisting of helium, argon and nitrogen.

12. The method of claim 10 further comprising introducing a second gas into said reactor chamber after said step of introducing oxygen.

13. The method of claim 12, wherein said second gas is selected from the group consisting of helium, argon and nitrogen.

14. A method for conducting atomic layer deposition of rhodium on an integrated circuit material layer, said method comprising the steps of:

positioning said material layer in a deposition region of a reactor chamber;

introducing dicarbonyl cyclopentadienyl rhodium into said deposition region of said reactor chamber to deposit a rhodium monolayer on said material layer at a temperature of about 100°C to about 200°C; and

introducing oxygen into said deposition region of said reactor chamber to remove carbon atoms from said rhodium monolayer.

15. The method of claim 14, wherein said atomic layer deposition is performed at a temperature of about 100°C to about 150°C.

16. The method of claim 15, wherein said atomic layer deposition is performed at a temperature of about 100°C.

17. The method of claim 14, wherein said dicarbonyl cyclopentadienyl rhodium is introduced into said reactor chamber at a rate of about 0.1 to about 500 sccm.

18. The method of claim 17, wherein said dicarbonyl cyclopentadienyl rhodium is introduced into said reactor chamber at a rate of about 5 sccm.

19. The method of claim 14, wherein said oxygen is introduced into said reactor chamber at a rate of about 10 to about 500 sccm.

20. The method of claim 19, wherein said oxygen is introduced into said reactor chamber at a rate of about 50 sccm.

21. The method of claim 14 further comprising introducing helium into said reactor chamber after said step of introducing said dicarbonyl cyclopentadienyl rhodium and before said step of introducing oxygen, at a rate of about 50 sccm and for about 5 seconds.

22. The method of claim 14 further comprising introducing helium into said reactor chamber after said step of introducing oxygen, at a rate of about 50 sccm and for about 5 seconds.

23. A method for conducting atomic layer deposition of rhodium on an integrated circuit material layer at a temperature of about 100°C to about 200°C, comprising the steps of:

positioning said material layer in a deposition region of a reactor chamber;

introducing dicarbonyl cyclopentadienyl rhodium into said reactor chamber at a rate of about 0.1 to about 500 sccm and for about 0.1 to about 30 seconds to deposit a rhodium monolayer on said material layer;

introducing a first purge gas at a rate of about 10 to about 200 sccm and for about 0.1 to about 10 seconds;

introducing oxygen into said deposition region at a rate of about 10 to about 200 sccm and for about 0.1 to about 10 seconds, and removing carbon atoms from said rhodium monolayer; and

introducing a second purge gas at a rate of about 10 to about 200 sccm and for about 0.1 to about 10 seconds.

24. The method of claim 23, wherein said atomic layer deposition of rhodium is conducted at a temperature of about 100°C.

25. The method of claim 23, wherein said dicarbonyl cyclopentadienyl rhodium is introduced into said reactor chamber at a rate of about 5 sccm and for about 5 seconds.

26. The method of claim 23, wherein said oxygen is introduced into said reactor chamber at a rate of about 50 sccm and for about 5 seconds.

27. The method of claim 23, wherein said first and said second purge gases are each introduced into said reactor chamber at a rate of about 50 sccm and for about 5 seconds.

28. A method of forming a capacitor comprising the steps of:

forming a first and second electrode;

forming a dielectric layer between said first and second electrode; and

wherein at least one of said first and second electrode is formed by conducting atomic layer deposition of a rhodium group metal precursor.

29. The method of claim 28, wherein said rhodium group metal precursor comprises an organic rhodium group metal precursor having the formula Ly[Rh]Yz, wherein L is independently selected from the group consisting of neutral and anionic ligands; y is one of {1, 2, 3, 4}; Y is independently a pi-orbital bonding ligand selected from the group consisting of CO, NO, CN, CS, N_2, PX_3, PR_3, $P(OR)_3$, AsX_3, AsR_3, $As(OR)_3$,

SbX_3, SbR_3, $Sb(OR)_3$, NH_xR_{3-x}, CNR, and RCN, wherein R is an organic group, X is a halide and x is one of {0, 1, 2, 3}; and z is one of {0, 1, 2, 3, 4}.

30. The method of claim 29, wherein said rhodium group metal precursor is dicarbonyl cyclopentadienyl rhodium.

31. The method of claim 28, wherein said atomic layer deposition is performed at a temperature of about 100°C to about 200°C.

32. The method of claim 28, wherein said rhodium group metal precursor is introduced into a reactor chamber at a rate of about 0.1 to about 500 sccm.

33. The method of claim 28, wherein said rhodium group metal precursor is introduced into said reactor chamber at a rate of about 0.1 to about 5 sccm.

34. The method of claim 32 further comprising the step of introducing oxygen into said reactor chamber at a rate of about 10 to about 500 sccm.

35. The method of claim 34, wherein said oxygen is introduced into said reactor chamber at a rate of about 10 to about 200 sccm.

36. The method of claim 34 further comprising introducing a first gas into said reactor chamber after said step of introducing said rhodium group metal precursor and before said step of introducing oxygen.

37. The method of claim 36, wherein said first gas is selected from the group consisting of helium, argon and nitrogen.

38. The method of claim 36 further comprising introducing a second gas into said reactor chamber after said step of introducing oxygen.

39. The method of claim 38, wherein said second gas is selected from the group consisting of helium, argon and nitrogen.

40. A method of forming a rhodium upper electrode of a capacitor in an insulating layer of a substrate, comprising the steps of:

forming a conductive layer;

forming a dielectric layer over said conductive layer; and

forming a rhodium layer by atomic layer deposition at a temperature of about 100°C to about 200°C over said dielectric layer.

41. The method of claim 40, wherein said step of forming said rhodium layer by atomic layer deposition comprises introducing said substrate in a deposition region of a

reactor chamber, and introducing dicarbonyl cyclopentadienyl rhodium into said reactor chamber.

42. The method of claim 41, wherein said dicarbonyl cyclopentadienyl rhodium is introduced at a rate of about 0.1 sccm to about 500 sccm.

43. The method of claim 41, wherein said dicarbonyl cyclopentadienyl rhodium is introduced into said reactor chamber at a rate of about 0.1 sccm to about 5 sccm.

44. The method of claim 41, wherein said step of forming said rhodium layer by atomic layer deposition further comprises introducing oxygen into said reactor chamber.

45. The method of claim 44, wherein said oxygen is introduced into said reactor chamber at a rate of about 10 to about 500 sccm.

46. The method of claim 44, wherein said oxygen is introduced into said reactor chamber at a rate of about 10 to about 200 sccm.

47. A method of forming a rhodium lower electrode of a capacitor in an insulating layer of a substrate, comprising the steps of:

forming a rhodium layer by atomic layer deposition at a temperature of about 100°C to about 200°C;

forming a dielectric layer over said rhodium layer; and

forming a conductive layer over said dielectric layer.

48. The method of claim 47, wherein said step of forming said rhodium layer by atomic layer deposition comprises introducing said substrate in a deposition region of a reactor chamber, and introducing dicarbonyl cyclopentadienyl rhodium into said reactor chamber.

49. The method of claim 48, wherein said dicarbonyl cyclopentadienyl rhodium is introduced at a rate of about 0.1 sccm to about 500 sccm.

50. The method of claim 49, wherein said dicarbonyl cyclopentadienyl rhodium is introduced into said reactor chamber at a rate of about 0.1 sccm to about 5 sccm.

51. The method of claim 48, wherein said step of forming said rhodium layer by atomic layer deposition further comprises introducing introducing oxygen into said reactor chamber.

52. The method of claim 51, wherein said oxygen is introduced into said reactor chamber at a rate of about 10 to about 500 sccm.

53. The method of claim 52, wherein said oxygen is introduced into said reactor chamber at a rate of about 10 to about 200 sccm.

54. A method of fabricating a DRAM cell container capacitor comprising the steps of:

forming a first and second conductive layer; and

forming a dielectric between said first and second conductive layer, at least one of said first and second conductive layer being a rhodium layer formed by atomic layer deposition of dicarbonyl cyclopentadienyl rhodium at a temperature of about 100°C to about 200°C and for about 5 seconds.

55. A capacitor comprising:

a first electrode and a second electrode;

a dielectric provided between said first electrode and said second electrode; and

at least one of said first and second electrode comprising a continuous ALD deposited rhodium film with reduced carbon content.

56. A capacitor comprising:

a first electrode and a second electrode;

a dielectric provided between said first electrode and said second electrode; and

at least one of said first and second electrode comprising a reduced-carbon rhodium film formed by rhodium atomic layer deposition at a temperature of about 100°C to about 200°C.